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Planning for a Bull Market for Wetlands

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Commentary

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INTRODUCTION

Do wetlands have a value on the open market only as targets for destruction? This was an assumption long held by business and conservation interests alike. But we may be entering an era when this assumption is no longer valid. The potential role of wetlands in producing biofuels, reducing greenhouse gases, alleviating water pollution, conserving rare species, and mitigating wetland losses may turn some wetlands into valuable assets.

The search for a greater degree of energy independence has led to extensive research and development of homegrown biofuels that could be used in place of oil. To avoid using cropland for biofuels, research has focused on plants that grow in and adjacent to wetlands. On the drawing boards are plans for using wetlands to cultivate biofuels from algae and various exotic and bioengineered plants.

Programs to control greenhouse gases may provide even greater potential profits for wetlands managers. Wetlands store vast amounts of carbon, but they also emit large amounts of methane and smaller amounts of nitrous oxide. In a world in which greenhouse gas trading offsets have significant market value, the prospect of managing wetlands to reduce net emissions of greenhouse gases will be enticing.

Wetlands managers are also showing increasing interest in trading systems that would provide credits for reduction of water pollution or conservation of wildlife. We are already developing techniques to manage wetlands to reduce nitrogen and phosphorus pollution from wastewater treatment. Studies of methylmercury formation may lead to ways of managing wetlands to reduce the problem created by the accumulation of mercury in fish and wildlife. Species conservation banks have been growing and are receiving increased attention.

Wetland mitigation banks, which allow a wetland developer to get payments for mitigating wetland losses elsewhere, are proving increasingly popular. In addition, wetland mitigation banks recently received a boost from new federal regulations that make such banks the preferred choice for off-site mitigation of destroyed wetlands.

Some of these market-oriented projects may be quite beneficial to society while remaining compatible with the other nonmarket values that wetlands provide, such as flood control and wildlife protection. On the other hand, it is easy to imagine projects that might be incompatible with other important functions. The basic problem is that we have few standards to help us draw the line. Planners and lawyers are only beginning to give thought to wetland management. Past arguments have largely turned on whether to destroy wetlands or leave them alone.

This commentary discusses some of the types of wetland-based projects that government agencies may be asked to evaluate. Eventually, we can hope for a coordinated effort by scientists, planners, and lawyers to come up with standards and procedures for such evaluation. But before any changes in law and policy will be made, state and local government officials are likely to be asked to evaluate individual wetland management projects. The purpose of this commentary is to highlight the wide range of issues that may need to be addressed in making such an evaluation.

WETLAND BIOFUELS

The Search To Replace Petroleum

Projects to grow biofuels are receiving significant government support in the United States and throughout the world. The projected high prices of fossil fuels have made many renewable energy projects appealing economically on their own merits. Such projects are also stimulated by a widespread interest in achieving a greater degree of energy independence. And biofuel projects are particularly attractive if they can also be designed to get carbon credits.[1]

Biofuels have attracted big investments. Producers make lots of ethanol from corn and biodiesel from soybeans or rapeseed, but by using crops of agricultural value, biofuel producers have been accused of increasing food prices. Lester Brown, head of the Earth Policy Institute, says: "[W]e are witnessing the beginning of one of the great tragedies of history. The United States, in a misguided effort to reduce its oil insecurity by converting grain into fuel for cars, is generating global food insecurity on a scale never seen before."[2]

Furthermore, some scientists argue that "because farmers worldwide are responding to higher prices and converting forest and grassland to new cropland, corn-based ethanol, instead of producing a 20 percent savings, will nearly double GHG [greenhouse gas] emissions over 30 years."[3] This has led to the search for biofuel products on

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lands that would not replace existing agriculture[4] but would be capable of high productivity.[5] Wetlands fit that bill.[6]

Wetland Vegetation

In the United States, the search for biofuels that might replace petroleum has included studies involving the harvesting of wetland vegetation. Developers have proposed a plantation of the Asian giant reed, Arundo donax, near the Everglades,[7] over the strong objection of conservation groups who point to the plant's history of invasiveness.[8] Reed canary grass, *Phalaris arundinacea*, is also being tested for biofuel production in the United States, despite its reputation as an invasive wetland species.[9]

Other wetland species with invasive histories that are being tested for biofuel production include Chinese tallow (*Sapium sebiferum*) and castor bean (*Ricinus communis*), native to Africa. Some native American wetland species are being tested for biofuels elsewhere in the world, even though they have become invasive in some other countries. These include elderberry (*Sambucus canadensis*) and persimmon (*Diospyros virginiana*).[10]

Scientists have different opinions on the extent to which any nonnative plant should be used for biofuel production or greenhouse gas reduction. Some argue that the inevitable climate change that will occur over the next decades will make use of nonnative species necessary,[11] but many other scientists find this prospect alarming[12] and urge the development of tests to determine invasive potential[13] or the use of sterile triploid clones of nonnative species.[14]

In Southeast Asia, extensive oil palm plantations are being created by clearing and burning forested peatland swamps.[15] Palm oil converted to biodiesel fuel reduces carbon emissions from vehicles[16] but the GHG emissions produced by the peatland conversion significantly outweigh the reduction at the consumption end of the chain[17] and the loss of biodiversity is irreplaceable.[18] A recent analysis found "that replacing high-carbon and high-biodiversity forest or peatland with oil-palm monocultures in an effort to reduce the use of fossil fuels will accelerate both climate change and biodiversity loss."[19]

Global Seawater Inc. wants to channel seawater through canals into created wetlands and aquaculture ponds in Sonora, Mexico.[20] It claims that salt-tolerant plants such as salicornia could be converted to biofuel, and the creation of more acreage for seawater would mitigate sea level rise. Although many scientists fear the project's implications for groundwater, it is attracting venture capital.[21] Some countries provide subsidies for this kind of research and development project.[22]

One project to grow sugar cane in Kenya's Tana River delta, a major wetland area north of Mombasa, has attracted widespread opposition. Proposed sugar plantation developments would convert an area of over 270,000 acres into sugarcane plantations. The projects have received government permits, but litigation is pending. Sugar cane is a renewable and relatively inexpensive source of ethanol, but many local and international groups say the plantations and an accompanying ethanol production facility will have very detrimental effects on wetland functions.[23]

Transgenic Plants

The use of genetic manipulation to change the characteristics of existing plant species adds another element of controversy to biofuel production. Scientists are developing new plant cultivars that will be more tolerant of salinity and wet soils.[24] One of the plant groups seen as a potential target for genetic modification is the willow (*Salix spp.*), which is already quite tolerant of wet conditions.[25]

An Aspen Institute report, Biotechnology for Biofuels, concludes that "[t]he next horizon for biotechnology will be its impact on the development of improved biomass feedstocks for biofuels production." The ideal crop will grow on land not suitable for agriculture and have a high yield in tons per acre. "Preliminary results indicate that biomass yield increases of >300 percent in some grass species can be achieved via genetic engineering."[26] Scientists have sequenced the genomes of a wide range of plants and microorganisms as a predicate for developing cellulosic biofuels, including plants, bacteria, and algae that grow in wetlands.[27]

Algae

Scientists are undertaking wide-ranging research into the development of new types of algae as a source for biodiesel. "The use of algae has potential due to their easy adaptability to growth conditions, the possibility of growing in either fresh or marine waters and avoiding the use of land."[28] Some pilot projects grow algae in enclosed photobioreactors, but photobioreactors cost about 10 times as much as open ponds, so many pilot projects grow the algae in the reactor and then inoculate open ponds with the desired species.[29] When the pond eventually becomes contaminated with competing species, it is drained and sterilized before being reinoculated.[30] Such a process is feasible because algae can often be harvested repeatedly at intervals of 10 days or less, and are reported to produce up to 300 times more oil for biodiesel production than traditional crops on an area basis.[31]

Potential inputs to algae production include such diverse sources as CO_2 from power plants[32] and municipal sewage waste.[33] Anticipated outputs include jet fuel, biodiesel, or hydrogen. Significant amounts of venture capital have gone into a variety of algae production ventures, including money from Shell,[34] Chevron,[35] and Bill Gates[36] as well as limited amounts of government funding from various federal agencies. European Union countries have also provided funding; the Carbon Trust, an independent company backed by the British Government, has promised up to £26 million in funding for its Algae Biofuels Challenge.[37]

The scope of the plans of some of the entrepreneurs is eye-popping. Sapphire Energy, a well-financed American venture, talks about millions of barrels a day with tens of thousands of acres devoted to algae farms dotted all over the Gulf Coast and the Pacific Southwest.[38] It is unlikely that projects of this

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scale would get built quickly. Scientists are still searching thousands of algae species for one "to continually dominate an open pond and have desirable biofuel properties."[39] Not only are there awesome challenges involved in the basic research on the more than 40,000 species of algae that have already been identified,[40] plus the complications of genetic engineering of new varieties, but anyone pursuing permits for any sizable facility would need to deal with a host of government agencies.[41]

Opportunities and Risks

These examples merely illustrate the creative ingenuity that biofuels and other renewable energy projects attract.[42] Wetlands are still only a minor target for such projects, but if wetland biofuels can be developed that will reduce reliance on petroleum without destroying other important wetland functions, they would create important benefits. However, it is hard to foresee all of the potential risks these projects may create.[43]

At the 2008 meeting of the Conference of Parties to the Convention on Wetlands ("Ramsar"), many participants expressed concern about the potential impact of biofuels on wetlands. The conference resolved that

> Decisions on land use change must integrate adequate knowledge of the range of benefits, and their values, that wetlands provide for people and biodiversity. Decision making should, wherever possible, give priority to safeguarding naturally functioning wetlands and the benefits they provide, especially through ensuring the sustainability of ecosystem services, while recognizing that human-made wetland systems can also make a significant contribution to water and food security objectives.[44]

TRADING GREENHOUSE GAS CREDITS

The Carbon Market

Carbon trading (which usually also includes trading in other major GHGs) has developed into a big-money game that is still evolving in directions that are hard to predict. As of this writing, it has not had a big impact on wetlands, but if it follows the paths currently projected, traders will view the management of wetlands as tempting targets with high potential value.[45] Some such projects may be quite compatible with other beneficial wetland functions, but others may have highly adverse impacts. Discerning the differences will be challenging.

American companies are already active participants in the European Trading System.[46] The financial community looks forward eagerly to the expanded carbon trading. Many businesses expect that the United States will adopt some form of carbon trading law within a few years.[47] Groups of states, such as the Western Climate Initiative (which also includes some Canadian provinces) and the Regional Greenhouse Gas Initiative, a coalition of northeastern states, are already working on their own carbon trading programs.[48] "We see enormous opportunities for the financial industry," said the vice chairman of Deutsche Bank. "If leadership is there to create a Kyoto successor that is based on cap-and-trade, then it creates a global carbon market—and then we are in business."[49]

The assumption is that future trading systems will be based on a cap-and-trade law. The law will establish binding limits on the tons of greenhouse gases that certain categories of sources may emit. If a particular source chooses not to limit its own emissions, it can buy credits either (1) from another source that has limited its emissions more than the law requires, or (2) from the developer of a project that will reduce emissions in a way that the law does not require; such a project is referred to as an "offset."

Global Mixing Means Global Offsets

Although the idea that a chemical company could continue its GHG emissions in France by installing equipment to reduce emissions on a plant in Korea may sound counterintuitive,[50] the concept is based on the widely accepted scientific principle that greenhouse gases mix globally during their lifetimes in the atmosphere. Therefore, reducing emissions any place in the world is as good as any other. Or, as the traders like to say, a ton is a ton is a ton.

So the idea of offsets is scientifically sound. In addition, the offset project need not reduce the same gas as the gas that produces the emissions it is offsetting. The reduction only needs to add up to the same number of carbon dioxide equivalents as the gas that was emitted. Methane is 20 to 25 times as powerful as carbon dioxide, while nitrous oxide is about 300 times as powerful as carbon dioxide.

The United Nations' system of verifying Kyoto offset reductions has undergone significant growing pains.[51] The details of these controversies are beyond the scope of this commentary, but they involve examples such as (1) projects that cause huge reductions of the more potent greenhouse gases at chemical plants by installing cheap equipment that other plants use in the normal course of business; (2) projects that would probably have been undertaken anyway because they are economically profitable, such as some landfill methane capture and utilization projects; or (3) projects that will produce benefits only if one assumes that conditions will remain unchanged for decades, such as restoration of forests.

The rules defining a "good" offset should and will undergo change, but it is unlikely that offsets will disappear. First, the scientific logic on which offsets are based has not been seriously challenged: a ton is a ton, wherever and whatever. Second, many countries are setting emission caps that seem impossible to achieve without offsets,[52] which means that the price of credits might be high and create a big incentive for offset developers. One recent survey predicts that by 2020 carbon credits will sell for €30 per ton of carbon dioxide.[53] Third, all of the parties to an offset transaction will benefit if a project is declared to be a good offset worth lots of credits, so developing a trustworthy system of neutral oversight will be challenging.[54] Fourth, the participants in offset projects include some of the largest and most influential corporations in the world. The membership of the International Emission Trading Association (IETA) includes many big investment banks and multinational companies.[55] These guys don't play penny ante.

The technical literature on managing wetlands for GHG reduction is growing rapidly.

Natural Emissions

Although the arguments about climate change have focused on the issue of whether and how humans are changing the climate by emitting GHGs, it is well known that natural sources also emit large amounts of GHGs. If too many GHGs are the problem, then reducing natural GHG emissions will be as beneficial as reducing emissions from human-caused sources.[56]

Why are wetlands logical opportunities? First, some kinds of wetlands store enormous amounts of carbon in the form of submerged organic material, and might be managed in a way that stores more.[57] Second, the prevailing scientific opinion is that methane is responsible for some 15 percent of total GHG emissions,[58] and that natural wetlands cause about 25 percent of methane emissions.[59] Third, the 2007 Intergovernmental Panel on Climate Change (IPCC) report emphasized that some wetlands are significant sources of nitrous oxide, an even more potent GHG.[60] Fourth, the IPCC estimates that a doubling of carbon dioxide emissions would cause wetland methane emissions to increase by 78 percent.[61]

Going for the Gold

So if the goal of our laws was solely to reduce climate change—and right now the price of carbon credits is based on no other factor[62]—then alteration of wetlands based solely on GHG impact could be an alchemist's tempting pot of gold. C - NH_4 - N_2O = Au.

How much gold? Any project that might be planned today would need to speculate on the price carbon credits would bring when the project was completed.[63] But with credits in various world markets in the range of $20 per ton, and various economic models projecting even higher prices, the lure is great.[64]

Could this entire system collapse? It's possible, but not sufficiently likely so that we can ignore the system's implications. In a recession, politicians may be slower to adopt new regulations, and some economists argue that a carbon tax would be more efficient than a cap-and-trade law,[65] but many analysts think that new taxes would be even less popular.[66] Nevertheless, the possibility that the market will expand and the price of credits will remain high is sufficiently likely that it pays to think in advance about the potential impact of such projects on wetlands.

How Wetlands Affect GHGs

The technical literature on managing wetlands for GHG reduction is growing rapidly. Most of the studies identify particular factors that appear to affect the GHG conditions on specific wetlands, and few authors pose broad generalizations. The wide-ranging results of this research emphasize how complex and site-specific any analysis of the global warming potential (GWP) impact of any particular wetland can be.

Examples of the factors affecting wetland GHGs are discussed in the studies cited below, which represent only a small sample of the literature.

Water level. Wetland soils that are continuously underwater remain anaerobic—lacking in oxygen—which can increase their ability to store carbon.[67] However, bacteria that generate methane thrive in anaerobic conditions, so that deep, continuous water over wetland soils can increase methane emissions.[68] In some cases, the methane from the wetland may cause a net increase of GWP despite the carbon storage that takes place.[69]

Periodically draining wetlands can reduce methane emissions, even to the point of creating a methane sink,[70] but such drainage may increase carbon dioxide emissions,[71] and some studies conducted in tropical rice fields indicate that periodic drainage increases nitrous oxide emissions.[72] Natural periodic variations in water levels may also substantially reduce methane emissions,[73] but some research suggests that temporary reductions in water levels may increase the release of methane bubbles.[74] Restoring old wetlands by raising water levels can increase carbon storage,[75] but the timing and extent of carbon buildup remains difficult to predict.[76]

Climate. The peatlands in northern Eurasia and North America differ greatly from coastal mangrove wetlands and forested peat swamps in the tropics. The rising arctic temperatures in recent decades have caused more emissions of methane from northern wetlands.[77] Much of the arctic methane has been locked in permanently frozen ground —permafrost—and is being released as warmer temperatures cause the ground to melt in the summers.[78] Subarctic peat wetlands are also affected by temperature; some models predict that warming temperatures may increase methane emissions from such wetlands,[79] but it is unclear whether warming will increase or decrease carbon storage.[80]

One recent study of coastal tropical wetlands found that they absorb and hold 80 percent more carbon than wetlands in temperate climates,[81] and coastal wetlands, in their natural condition, may have only a modest adverse impact on methane or nitrous oxide.[82] Seawater inhibits methane emissions,[83] but if coastal wetlands are affected by runoff from fertilized agriculture or urban wastewater they may become substantial emitters of both methane and nitrous oxide.[84] Unfortunately, such runoff is more and more common throughout the world.[85]

Seasonality. Emissions of GHGs from wetlands often vary greatly over a year's time, not only in cold climates,[86] but in areas where rainfall is highly seasonal. A study in coastal wetlands on the Bay of Bengal found high rates of methane emissions in the November–January period and low rates in other months.[87] Thus even where the year-to-year climate may be relatively constant, at least one full year's measurement would be needed to ascertain GWP impact.

Flora. Numerous studies have tried to ascertain the extent to which different species of plants create different GWP impacts. For example, forested wetlands can store lots of carbon if harvest rotation is long,[88] but a study of a forested freshwater wetland in Louisiana found that the methane emissions created a net warming effect.[89] A study of sedges found that they increase methane emissions in wet periods but reduce it in dry periods.[90]

Some studies suggest that a greater diversity of wetland vegetation reduces

Federal and state agencies are already partnering with private projects to increase carbon sequestration in wetlands.

methane output.[91] Other studies found that particular species of plants seem to have adverse GHG impacts; for example, in an Irish bog, buckbean plants seemed to produce methane hotspots,[92] and in an Ohio wetland, common rush was more effective in lowering methane emissions than black willow.[93] Nitrous oxide may also vary with different species of wetland vegetation. A study of a Chinese wetland found that Manchurian wild rice stimulated nitrous oxide emissions.[94] In India, the pneumatophores produced by Grey mangroves were found to be conduits of increased emissions of both nitrous oxide and methane.[95]

Algal ponds have also been studied as potential sinks for carbon storage. One study hypothesizes that one hectare of algal ponds could store up to one ton of carbon dioxide every day.[96] Scientists are studying thousands of algae varieties both for carbon storage and biofuels.

Fire. Peat bog fires that occur from lightning strikes or human activities can instantly convert a carbon sink into a huge source of carbon emissions.[97] Because peat is an enormous storehouse of carbon, the United Nations Environment Programme (UNEP) peatlands study identified such fires "as one of the largest sources of CO_2 in the atmosphere." The burning of forested peat bogs in 1997 in Indonesia emitted some 2.6 billion tons of carbon, "equivalent to 40 per cent of global emissions from burning fossil fuels that year."[98]

Nitrates. Many natural wetlands have low nitrate concentrations, so the fact that they produce some nitrous oxide through denitrification does not make them significant sources of this powerful GHG.[99] However, human activities are increasingly directing runoff from fertilized agriculture into wetlands, substantially increasing nitrate volumes. One study found that wetland soils appear to convert a high proportion of fertilizer runoff to nitrous oxide rather than other nitrogen forms.[100]

In addition, the creation of wetlands for treatment of wastewater provides a major source of nitrates.[101] A study of Brazilian wetlands that absorbed runoff from sugarcane fields suggested that the nitrous oxide emissions from the wetland cancelled out the savings from carbon storage.[102] Similar conclusions were reached in a study of wastewater wetlands in the Netherlands.[103] Nitrates may also affect methane production. One study suggested that the addition of wastewater to mangrove wetlands may increase methane production and destroy the ability of the trees to reproduce;[104] in a Russian peat bog, however, the addition of nitrates apparently reduced methane emissions.[105]

Sulfates. Many tropical coastal wetlands have acid sulfate soils.[106] A number of studies have shown that even small amounts of sulfates can reduce the production of methane in wetlands.[107] Coastal wetlands may receive enough sulfate from seawater to neutralize methane production.[108] But seasonal rainfall may sometimes reduce the effectiveness of sulfates.[109]

Studies that simulated the effects of acid rain on inland wetlands concluded that the components of typical acid rain actually reduced methane emissions.[110] Both sulfates and nitrates seemed to have that effect.[111] Similar results were found in a Russian study.[112]

Fauna. Marsh snails have caused extensive die-offs of wetland vegetation in southern U.S. coastal areas, presumably because overharvesting of their predators led to an explosion of snail populations.[113] By flooding streams in northern regions, beavers have contributed to higher methane emissions.[114] Muskrats and related species dig holes in dikes and may cause wetland drainage.[115] Huge flocks of geese have had dramatic impacts on Arctic wetlands, affecting their GHG balance unfavorably by destroying vegetation.[116] On the other hand, one study found that Bewick's swans reduce wetland methane emissions because their foraging causes bioturbidity.[117]

Time. Where the climate tends to vary substantially from year to year, determining the long-range effect of a wetland on GWP may require measurement over long periods of time [118] and remains difficult to predict.[119] The need to normalize the data for year-to-year climate variations adds another variable to the analysis.[120] Newly formed wetlands are not likely to accumulate the stored carbon typical of a natural wetland for decades[121] and may never achieve comparability.[122]

The temporal effect of ongoing climate change must also be considered. If the IPCC reports are to be used as a basis for awarding credits, then the calculations should recognize the IPCC's predictions that a substantial degree of climate change will happen before any mitigation measures can be effective. For example, if climate change is likely to increase coastal water levels, that impact should be taken into account in evaluating a coastal wetland.

These brief, nontechnical descriptions of the results of some technical studies should not be relied on as summaries of the studies themselves. The important points are (1) the wide variety of factors being studied; (2) the fact that the studies are being carried out in varying types of wetlands throughout the world; and (3) the site-specific nature of so many of the results.[123] These situations illustrate the need for a great deal of additional research.

Federal and state agencies are already partnering with private projects to increase carbon sequestration in wetlands. The U.S. Geological Survey is beginning to provide grants for "carbon farms"— wetlands created to store carbon[124]—and the U.S. Fish and Wildlife Service (USFWS) is working with private landowners to replant forested wetlands.[125] State and local agencies will need a lot of scientific expertise to evaluate new wetland projects designed to improve GHG performance.

If the analysis of biofuel and carbon credit values were not complex enough, consideration must be given to the possibility that wetland management may produce market-derived values from a number of other sources. These include water pollution control, water quality trading, toxic mercury control, species conservation banking, and wetland mitigation banking. Furthermore, the process of managing wetlands may involve informal tradeoffs through environmental assessments and local development exactions.

The idea of using banking systems to help finance wetland biodiversity is more recent and grew in recognition of the need to protect quite large wetland areas in certain places.

WATER QUALITY TRADING

The U.S. Environmental Protection Agency (EPA) has been heavily promoting trading programs as an efficient way to reduce air pollutant emissions. The agency has also encouraged the states to experiment with trading systems to reduce water pollution. Although these programs are not as widespread as the air pollution programs, the possibility of receiving credits under a water quality trading program is one that a wetlands manager would want to consider if it is available.

Treatment Wetlands

Both the EPA and the U.S. Department of Agriculture have been encouraging states to develop programs for water quality trading.[126] Effluent that is discharged directly into rivers from sewage treatment plants or factories carries heavy loads of nitrogen and phosphorous downstream. Agricultural fertilizers add these same elements to water bodies through runoff. If certain treatment methods can reduce nutrient inputs more cheaply than others, a trading program can be used to promote use of the most efficient methods.[127] The most common example has been one in which a regulated factory obtains credits for paying an unregulated agribusiness to establish buffer zones along the riverbank to reduce agricultural runoff.[128]

The problem of nutrient pollution is a serious one. In the Mississippi watershed, for example, such high quantities of nutrients remain when the river reaches the Gulf that oxygen content is lost and large areas can no longer support most marine life.[129] Similar "dead zones" are found in the Baltic Sea and other bodies of water.[130]

To alleviate this type of problem, efforts are underway throughout the world to restore riparian wetlands[131] and to construct treatment wetlands[132] to absorb more of these nutrients. "Because wetlands can be sinks for almost any chemical, applications of treatment wetlands are quite varied, with thousands of applications worldwide to treat domestic wastewater, mine drainage, non-point source pollution, storm water runoff, landfill leachate, and confined livestock operations."[133]

Seven states have programs in effect to allow statewide trading of water quality credits.[134] In some instances, constructed wetlands may serve as a source for tradable water quality credits, but it "has been an uphill battle."[135] Because there is no specific federal statutory authority for the program, the states have many different approaches and the overall effectiveness of the programs is hard to determine.[136]

Mercury

In the future, the opportunity to obtain water quality credits for wetlands may improve if methods of using wetlands to reduce the toxicity of mercury become well established. Mercury causes serious health problems for pregnant women and infants.[137] The primary source of mercury is airborne, but its health impacts begin after the mercury reaches water and is methylated and absorbed up the food chain to fish and wildlife. These issues do not fit neatly within our existing regulatory systems,[138] and at present there are no enforceable federal regulations of mercury emissions from power plants.[139]

Wetlands play a key role in the conversion of atmospheric mercury to the methylmercury (MeHg) that becomes bioaccumulated in fish and other wildlife.[140] A review of the literature in 2002 commented that "it is ironic that wetlands, landscape elements that both regulation and legislation have attempted to protect from disturbance, are the single most identifiable source of MeHg in terrestrial systems."[141]

The scientific understanding of methylation is still limited, but the nature of the water body in which methylation occurs appears to play an important role.[142] Measurements taken at a number of wetland sites have shown that wetlands export more MeHg than they receive.[143] Sulfate-reducing anaerobic bacteria that appear to be causing much of the methylation thrive in wetlands, particularly in wetlands where organic carbon and sulfate are common, such as those impacted by acid rain.[144]

Although the science remains in flux, biotechnologists are working on methods of wetland management that counteract or limit the methylation process.[145] Scientists have engineered wetland plants with bacterial genes that can convert MeHg to its volatile form; for example, experiments found that transgenic rice was able to convert MeHg to its less toxic form.[146] Similar experiments have been successful with cottonwoods.[147] Such research might eventually lead to regulations that would provide valuable credit for management of wetlands for MeHg removal.

SPECIES CONSERVATION BANKS

Species conservation banks have attracted considerable interest recently. Wetlands managers have had over a century's experience in managing wetlands for the benefit of wildlife; the USFWS, various state agencies, and nongovernmental organizations such as Ducks Unlimited have shown that wetlands can frequently be managed to improve habitat for wildlife.[148] Although much of the management has been financed by duck hunters, the managers have also learned how to provide habitat for other species in need of protection.[149]

The idea of using banking systems to help finance wetland biodiversity is more recent and grew in recognition of the need to protect quite large wetland areas in certain places. Many species suffer when their habitat is fragmented; their chances of survival improve if they can occupy a larger habitat that may be subject to less stress from changing conditions.[150] Amphibians, for example, often need both wetlands and some adjacent protected uplands in order to maintain stable populations.[151] Shorebirds that migrate long distances may require large protected areas at key points on their migratory routes; for example, the Red Knot (*Calidris canutus*) makes one of the longest yearly migrations of any bird, traveling 9,300 miles from Tierra del Fuego at the southern tip of South America to its Arctic breeding grounds, and relies on a specific area of Delaware Bay to fuel its spring migration.[152]

California's Program

California has had a program in place for more than a decade that encourages the development of reserves for the protection of rare species by allowing the

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managers of the reserve to sell shares in it to people who need the credits to mitigate for habitat destruction.[153] Some 40 conservation banks have been created, many of which are devoted to the protection of wetlands, including rare vernal pools and wetland-upland interfaces needed by rare amphibians such as the California red-legged frog.[154] The program differs from typical wetland banking by emphasizing the quality of the habitat protected rather than just the amount of acreage.[155] The USFWS supports the program, and has encouraged the development of similar programs in other states.[156]

The informal legal status of conservation banks outside California has made it difficult to collect comprehensive information about their existence and operations.[157] A study in 2003 found 76 places that were designated as conservation banks, not all of which were associated with state or federal programs.[158] Congress has not specifically addressed conservation banking for the protection of species, so the rules are set forth in guidance documents issued by the USFWS rather than in statutes or regulations, which creates a risk that future statutes could change the rules retroactively.[159] However, many of the conservation bank transactions are included in habitat conservation plans endorsed by the USFWS,[160] and such plans have been accepted by the courts as binding contracts.[161]

Biodiversity Offsets

The World Bank has promoted the use of conservation banks at the international level.[162] The United Nations Convention on Biological Diversity has encouraged the development of guidelines for "biodiversity offsets" and a number of countries have begun work on such programs.[163] A new NGO has been created specifically to work on this subject.[164]

Scientists are paying specific attention to the possibility of designing biodiversity banks that might receive carbon credits under the Kyoto Protocol's clean development mechanism system. Two Australian analysts suggest that the "convergence of schemes to sequester carbon and conserve biodiversity present an opportunity to revolutionize environmental management. If correctly harnessed, the power of carbon initiatives could fuel a major biodiversity renaissance."[165]

WETLAND MITIGATION BANKS

Are All Wetlands Equal?

Under federal law, a wetland that is destroyed can often be replaced by a different piece of land as long as that land is also "wet." This has led to many efforts to create wetlands that would be the equivalent in size to wetlands that developers wanted to destroy.[166] The mixed results of these efforts[167] led the EPA to ask the National Research Council (NRC) of the National Academies of Science and Engineering to study the effectiveness of wetland mitigation.[168]

The mitigation requirement arises under the permitting requirements of § 404 of the Clean Water Act, which requires developers to obtain a permit from the U.S. Army Corps of Engineers (Corps) to dredge or fill certain types of wetland.[169] Although the Corps' preferred alternative has been for the developer to redesign the project so it will not affect wetlands, many developers claimed that was not feasible and proposed to create new wetlands either on-site or in some other location, but the track record of this type of mitigation was not encouraging.[170]

The NRC found that the existing mitigation procedures needed to pay more attention to the long-term management of mitigation projects: "The presumption that once mitigation sites meet their permit criteria they will be self-sustaining in the absence of any management or care is flawed."[171] It recommended that if project redesign was not feasible the developer should be encouraged to buy shares in a large created or restored wetland that would be professionally managed to maintain wetland values over the long term.[172]

A Watershed Perspective

In 2008, the Corps issued new regulations that endorsed many of the recommendations of the NRC.[173] Wetland mitigation banks, which have been functioning in some areas for 20 years,[174] now get preferred status under the new regulations.[175] Development of wetland mitigation banks is encouraged in an attempt to produce larger wetland systems that will perform more functions more reliably.[176] Because a person who creates a new wetland may be able to sell shares in it to developers who need to produce wetlands equivalent to the wetland they will be removing,[177] the time lag between the destruction of a wetland and its replacement can be reduced.[178]

In addition, the regulations allow a mitigation bank to protect the permanence of existing wetlands if a watershed study has identified such preservation as a high priority.[179] The NRC had emphasized that "the mitigation program would achieve greater short- and long-term results by looking at each permitting decision over a broader space and longer time period." When a plan is "viewed from a watershed perspective over a long period, the purpose is to secure a desired matrix of wetland types and locations to achieve the goals of the Clean Water Act in the watershed."[180]

STACKING CREDITS

To what extent should a manager of a hypothetical wetland be given value separately for performing each of the following functions at the same time and place?

1. carbon sequestration
2. methane and nitrous oxide suppression
3. mitigating wetland destruction by others
4. performing wastewater treatment
5. protecting habitat of rare species
6. creating valuable biofuel

At first blush, every wetland management entrepreneur would relish the possibility of getting paid separately for performing each of the whole range of valuable functions discussed in this commentary, and many conservation organizations see advantages of combining multiple credits.[181] But what is the risk that the stacking will be banned as "double-dipping?"[182]

Double-dipping

The dictionary defines double-dipping as "the act or practice of receiving more

Many of the trading programs have tried to develop rules that ensure that credits or other incentives are given to projects that would not have been feasible without the incentive.

than one income or collecting double benefits from the same employer or organization."[183] But no law prevents this if it is an open transaction between parties who have full information. Corporations regularly pay officers a salary, bonus, various benefits, and stock options, each designed to reward a certain kind of performance. If there is full disclosure of information, and the rules of each separate program are met, then double-dipping should not be disqualified.

Despite the lack of any precise legal definition, double-dipping has become the slogan used by people who are concerned that trading programs may unduly reward project proponents. The concern is legitimate, but the complexity of the processes by which such projects are put together sometimes makes it very difficult to decide how many dips are too many.

For example, if the landowner received funds from one of the many government grant programs designed to promote wetland conservation,[184] it could be argued that it would be an inappropriate form of double-dipping to allow the landowner to earn credits without deducting the cost of the compensation already received. On the other hand, farmers have become experts in piling various kinds of subsidies and incentives from the federal government on top of each other, and this practice is encouraged by agriculture agencies.[185] Where this is the normal way of doing business, should a wetland owner be prevented from stacking various types of credits on top of these grants?

Additionality

Could biofuel projects also get wetland mitigation credits if the sale of the biofuel in a private market created compensation for the wetland owner? What if the biofuel plants also reduced the methylation of mercury or reduced the emission of methane? If a wetland improvement project could generate value on the private market and also performed valuable environmental functions, it would seem unfortunate to discourage it. Yet if the sale of the biofuel were so profitable that the project would have been undertaken in any event, the allocation of scarce credits might better be reserved for projects that would not have gone forward without them.

Many of the trading programs have tried to develop rules that ensure that credits or other incentives are given to projects that would not have been feasible without the incentive. The term "additionality" has been coined to express this idea. In the hypothetical example above, if each of the trading programs insisted on additionality, then the project developer would need to convince them that all of the separate incentives were necessary to make the project feasible.[186]

Permanence

How long will a particular project produce the results it seeks to achieve? This can often be one of the most difficult issues to resolve. The proponent may argue that unless the credits are received up front it will be impossible to undertake the project. But who can prove that a project will work as planned and that it will not be destroyed by fire, flood, or other unexpected events?

The debate on this issue has been particularly intense in the United Nations Clean Development Mechanism program in regard to forestry. The Kyoto Protocol gives credits for afforestation and reforestation, but the regulations limit the time period for which the credit can be awarded. When the credit expires, new temporary credits can be awarded if the project is performing properly.[187]

Temporary credits that are renewed periodically may better motivate a project manager to protect and maintain the project.[188] If the award of credits is made periodically as the project evolves, the government will also feel more secure that the scarce credits are not being wasted, but this security may come at the expense of the most innovative and promising projects that may never receive financing because of their lack of a track record. Cautious bureaucrats may tend to approve only the most time-tested types of projects that follow authorized models, thereby stifling innovation.[189] On the other hand, direct research and development grants may be the most appropriate way to encourage innovation.

Leakage

Another issue that often arises is known as "leakage." In the hypothetical, we should ask if the project would have indirect adverse impacts beyond the project's boundaries. Would the wetland plants invade neighboring areas? Would the suppression of methane involve adding chemicals that would have adverse impacts downstream? Would the use of the wetlands for sewage treatment make it unfeasible to employ a better form of treatment?[190]

Ad Hoc Mitigation

There are no rules of general applicability to decide whether the stacking of credits should be prohibited as double-dipping. The development of such rules seems unlikely because of the many ways that a wetland developer can obtain value indirectly. As every practitioner knows, negotiating tradeoffs is one of the primary activities of a land use or environmental lawyer. Much of this work is done in an informal context when negotiating issues relating to some particular project, and the legal basis for enforcement of such negotiations may be shaky.

Without venturing into detail, there are a few mechanisms under which such trading takes place. A vast and undocumented trading process has taken place under the National Environmental Policy Act (NEPA) and similar state statutes. Although most of the scholarly attention has been directed to NEPA's requirement of an environmental impact statement (EIS), less than one percent of the cases under NEPA reach the EIS stage. Instead, the proponent prepares an environmental assessment and negotiates with the stakeholders about what changes in the design or compensatory mitigation is required in order to avoid a challenge to the failure to prepare an EIS. The typical resolution is a "mitigated FONSI," which is a "finding of no significant impact" based on the fact that the proponent's

The IPCC's reports suggest that the wetlands themselves will be changing in response to climate change that has already become unstoppable.

proposed mitigation will balance any adverse impacts to the point of insignificance.[191] Although these mitigation commitments have not always been put into enforceable form,[192] and comprehensive data about them will probably never become available, there are certainly cases where they have resulted in a great deal of improvement to the environment.[193]

But applying these concepts to particular cases is not easy. For example, suppose a highway builder destroys some wetland acreage but proposes to create new wetlands in place of the usual borrow pits. Would the project have required an EIS if traditional borrow pits had been used? How can we ever be sure? And how would you value the time and expense of preparing the EIS? An equally undocumented forum for trading takes place at the local level when land developers agree, or are required, to do things to benefit the local community in exchange for a rezoning or other form of development permission.

Administrators of trading programs are all searching for ways to allocate credits and incentives where they will do the most good for the particular values that they are trying to protect. Perhaps some day there will be clearly defined rules that apply generally to all of these programs, but until then the developers of projects and the agencies that review them will be trying to make the best judgment in the face of vague rules and continually evolving science.

CONCLUSION

Reviewing Projects

What are the implications of all of this research and marketing for government officials who will be asked to review proposed projects?

First, they should get a thorough analysis of the reliability of the project's potential impact. The profit these projects plan to generate should enable the developer to finance such studies by independent experts.

Second, don't be surprised if all that the scientists can tell you is "let's try it and wait and see." Adaptive management may be feasible for the developer if credits will be given to the project periodically based on periodical results.[194]

Third, remember that leaving wetlands alone may not be an option for maintaining the status quo.[195] The IPCC's reports suggest that the wetlands themselves will be changing in response to climate change that has already become unstoppable.[196] These changes are likely to produce complex and unpredictable feedback effects[197] especially for coastal wetlands.[198]

Breakthroughs and Shell Games

This commentary should really be viewed from at least two perspectives. First, the interplay of all of these programs provides challenging opportunities to develop new, creative methods of wetlands management that could provide great benefits for a number of important objectives. Scientists, planners, and lawyers ought to focus on ways to ensure that future regulations will encourage such projects.

Second, the large amounts of money at stake will tempt project developers to find loopholes in whatever regulations are adopted, so public scrutiny must be timely, comprehensive, and detached. Processes to make scientific expertise available for such reviews are needed.[199]

A third perspective, of course, would consider the basic issue of whether the unbundling of nature into marketable commodities is desirable and consistent with an overall national wetlands policy, but I'll save that discussion for another occasion.

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